IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Mochizuki, et. al
Application No. 10/766,986
Filing Date: December 24, 2003
Group Art Unit: 2871
Examiner: Andrew Schechter

Title: LIQUID CRYSTAL DISPLAY DEVICE

DECLARATION

PURSUANT TO 37 C.F.R. 1.132

I, Akihiro MOCHIZUKI, declare and state that I graduated from Department of Chemistry, Faculty of Natural Science, The University of Tokyo in March 1980 and obtained Natural Bachelor of Science; and also obtained Doctor of Engineering form Tokyo University of Agriculture and Technology, concerning studies on liquid crystal display devices. I have been employed by Fujitsu Laboratories, Ltd., since April, 1980, during which time I have been engaged, among others, in the research and development in the field of liquid crystal display devices. Thereafter, I have been employed by Displaytech, Inc. (USA), since 1998 to 2002, during which time I have been engaged, among others, in the research and development in the field of flat panel display devices such as liquid crystal display devices and plasma display devices. In particular, 15 years at Fujitsu Laboratories, Ltd., and 5 years at Displaytech, Inc., I have been engaged in the research and

development in the field of ferroelectric liquid crystal displays. I have established Nanoloa, LLC (USA), in December, 2002, during which time I have been engaged, among others, in the research and development in the field of liquid crystal display devices. Thus, I am very familiar with the fabrication, analysis and properties of various liquid crystal display devices.

My expertise in the field of liquid crystal displays is endorsed by many responsibilities of scientific paper reviews such as Society for Information Display, Applied physics both for American Physics Society and Japan Physical Society, Chemical Physics for American Chemical Society, and so on.

I understand that the above application has been rejected based on Takatori (U.S. Patent No. 6 040 889); Tanaka (U.S. Patent No. 5 847 799); and Kitayama (U.S. Patent No. 5 583 682). In order to show the differences between the subject matters of Takatori, Tanaka and Kitayama and the subject matter of U.S. Patent Application Ser. No. 10/766,986 (hereinafter, referred to as the subject application"), the following experiments were conducted under my control.

Experiment 1 deals with a test on a liquid crystal device of Tanaka (U.S. Patent No. 5 847 799), wherein a triangular voltage wave form is applied the Tanaka's device, and the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular

waveform voltage) generated thereby is confirmed.

Experiment 2 deals with a test on a liquid crystal device of Takatori (U.S. Patent No. 6 040 889), wherein a triangular voltage wave form is applied the Takatori's device and the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated thereby is confirmed.

Experiment 3 deals with a test on a liquid crystal device of Kitayama (U.S. Patent No. 5 583 682), wherein a triangular voltage wave form is applied the Kitayama's device, and the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated thereby is confirmed.

Experiment 4 deals with a test on a liquid crystal device according to the subject application, wherein a triangular voltage wave form is applied the device of the subject application, and the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated thereby is confirmed.

Experiment 1

(Test on Tanaka's device)

(1) Fabrication of device

We prepared Tanaka's devices based on the description

at the section: "DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS". According to the "First Embodiment", we followed Tanaka's device. Although Tanaka's device was described in the specification thereof using TFT substrate, we used ITO coated glass substrates. This difference between use of TFT substrates and ITO substrates does not create any substantial difference in terms of the purpose of this particular verification. Tanaka does not disclose any particular liquid crystal alignment materials. It says that Tanaka's device used high molecular material such as PI (supposed to be poly-imide). Therefore, we assumed to use PI material providing homogeneous liquid crystal molecular alignment which was specified in Tanaka. The used PI material was RJM-1 199 provided by Nissan Chemical Industries, Ltd. The liquid crystal layer thickness also did not show any particular thickness in Tanaka, but Tanaka describes that the thickness is set smaller than one pitch (natural pitch) of the helical structure of the used liquid crystal mixture. We used our in-house mixture showing smectic CA phase at room temperature, and having natural helical pitch of 1.6 micron. Therefore, according to the requirements of Tanaka, we set the liquid crystal layer thickness 1.3 micron.

Although above prepared 'Tanaka's devices" have some assumption in their preparation due to lack of detailed description of panel preparation in Tanaka, they were completely consistence with requirement from at least claims at claim 1, claim 2, claim 3, and claim 4 of Tanaka.

(2) Confirmation of peak-shaped current

Using above prepared "Tanaka's devices", we made a

transient current measurement using LC properties measurement system model 6254 manufactured by Toyo Corporation.

Fig. 1 shows the result of transient current with Tanaka's device. +/- 5 V, 0.2 Hz of triangular waveform voltage was repeatedly applied to the Tanaka's device. As it is obviously shown in Fig. 2, Tanaka's device shows one clear peak current to the applied triangular waveform voltage. This clear peak was corresponding to transient peak current due to polarization switching from one state to the other state, respectively. As Tanaka mentions in its line 5 to 7; Claim 1, the Peak is the result of the move from "the first ferroelectric phase aligning state" to "the second ferroelectric phase aligning state". The observed shoulder Peak was due to ion movement as explained in the reference: "Recent Measurement of Liquid Crystal Material Characteristics": by M. Inoue, K. Takatoh, and S. Kobayashi published in International Display Workshop (IDW) '06, paper number LCT7-1 page 647 (2006). It was not necessary to describe our experimental results showing at least one major peak current based on spontaneous polarization switchings Tanaka describes that there are two different ferroelectric phase states in the Tanaka's device, and each ferroelectric phase shows its own spontaneous polarization, and also these two mixed phases result in averaged single state at the Claim 1, Claim 2, Claim 3 and Claim 4 of Tanaka. Therefore both with our own followed experiments based on the Tanaka's description and Tanaka claims acknowledges existence of spontaneous polarization in the Tanaka's devices and the existence of spontaneous polarization was proved by our experiment as showing

transient peak current.

(Results of Experiment)

Fig. 1(A) is schematic sectional views showing the arrangement of "anti-ferroelectric" liquid crystal molecules in Tanaka's device, and Fig. 1(B) is schematic perspective views showing the arrangement thereof.

Fig. 2 is a graph showing the results of the spontaneous polarization measurement of "anti-ferroelectric" liquid crystal molecules in Tanaka's device. As shown in this graph, this device showed both of "polarization switching peak current from downward spontaneous polarization to upward spontaneous polarization" (switched spontaneous polarization in this case was "Q = 36 nC/cm2"), and "polarization switching peak current from upward spontaneous polarization to downward spontaneous polarization" (switched spontaneous polarization in this case was "Q = 27 nC/cm2").

These "Q value" was obtained in the following manner.

Q value" was lead from following calculation. Fig. 2 shows voltage dependent transient current The horizontal axis shows time, which means voltage. Because, we scanned triangular wave form voltage with 0.2 Hz. This creates continuous change of allied voltage. Therefore, the horizontal line shows applied voltage change. Since voltage times current leads total amount of charges transferred along with liquid crystal molecular switching, the near triangular shape area in the Fig. 2 shows total amount of switched charges in the panel. We used ITO electrode area

of 3. 14 cm2 panel, therefore, unit switched charges: Q nC/cm2 was obtained.

Experiment 2

(Test on Takatori's device)

(1) Fabrication of device

A liquid crystal display device was fabricated according to Example of Takatori (column, line to column, line). More specifically, this device was fabricated in the following manner.

According to description at the Example section, we fabricated Takatori's device as following. As same as in the case of Tanaka's device, there was no particular description in Takatori what kind of alignment layer was used for this example, so that we again applied RN-1 199 from Nissan Chemical Industry. The patent says at Example 1 section that the measured pre-tilt after rubbing is 1.2 degrees. RN-1199 was well known to provide 1 to L2 degrees of pre-tilt angle by mechanical rubbing. The layer thickness of the panel was set at 1.8 micron according to the Example 1 of Takatori. Used "anti-ferroelectric liquid crystal mixture" was a special mixture provided by Mitsubishi Gas Chemicals. This mixture has large spontaneous polarization of 140 nC/cm2.

(2) Confirmation of peak-shaped current

By use of the thus fabricated device, the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated

thereby was confirmed in the same manner as in Experiment 1.

(Results of Experiment)

Fig. 3 is schematic sectional views showing the arrangement of liquid crystal molecules in Takatori's device and Kitayama's device (i.e., mixed polarization panels).

Fig. 4 is a graph showing the results of the spontaneous polarization (i.e., polarization switching peak currents representing different domains of polarizations) measurement of the mixed polarization panels according to Takatori and Kitayama. As shown in this graph, this device showed polarization switching peak current from downward spontaneous polarization to upward spontaneous polarization. In this case, there were two peaks representing different portions of polarization domains. The switched spontaneous polarization for the peak P1 was "Q = 18 nC/cm2", and the switched spontaneous polarization for the peak P2 was "Q = 12 nC/cm2".

Due to conflict at boundaries between downward and upward spontaneous polarization areas, relatively conflict free area of downward spontaneous polarization area switches fast, and follows conflict boundary area. These experimental results clarify existence of local spontaneous polarization. Total existing spontaneous polarization was 18 to 12 nC/cm2 : 18 - 12 = 6 nC/cm2. This amount of net spontaneous polarization was provided by Kitayama (USP 5583682), and Takatori (USP 6040889).

In this experiment, an asymmetric amount of switched spontaneous polarization suggests that total numbers of upward spontaneous polarization and downward spontaneous polarization were not equal. Total area of spontaneous polarization at no applied voltage was 36-27 = 9 nC/cm2. However, there were total amount of 36 nC/cm2 of downward spontaneous polarization and 27 nC/cm2 of upward spontaneous polarization area in the case of Tanaka (USP 5847799).

Figs. 5 and 6 show a procedure for calculating the switched spontaneous polarization for the peaks P1 and P2 in this experiment.

Experiment 3

(Test on Kitayama's ferroelectric device)

(1) Fabrication of device

A liquid crystal display device was fabricated according to Example 1 of Kitayama (column 6, line 60 to column 11, line 11). More specifically, this device was fabricated in the following manner.

Kitayama's devices were prepared as following. According to "EXAMPLE 1" of Kitayama, we used LQ-1802 precursor type of poly-imide. Using nylon-base rubbing cloth, we made a parallel rubbing. The liquid crystal panel gap was set by using 1.2 micron average diameter spacer balls. After we filled similar type of ferroelectric liquid crystal mixture with CS-1014 provided by Chisso Chemicals, the filled panel was kept - 9 degrees C, 15 hours according

to the description at the section of EXAMPLE 1 in Kitayama. Then, the panel was wormed upto 30 degrees C taking 3 hours as described at the same section of the Kitayama. After this preparation, the panel showed two different alignment regions as described in the Patent. Therefore, this panel had at least two different alignment regions unlike our patent claims.

(2) Confirmation of peak-shaped current

By use of the thus fabricated device, the presence or absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated thereby was confirmed in the same manner as in Experiment 1.

(Results of Experiment)

Fig. 7(A) is schematic sectional views showing the arrangement of Kitayama's ferroelectric liquid crystal molecules in Tanaka's device, and Fig. 7(B) is schematic perspective views showing the arrangement thereof.

Fig. 8 is graphs showing the results of the spontaneous polarization measurement of "ferroelectric" liquid crystal molecules in Kitayama's ferroelectric device. As shown in these graphs, this device showed clear peak current.

Experiment 4

(Test on device of the subject application)

A liquid crystal display device was fabricated

according to Example 1 (page 50, line 16 to page 52, line 4) of the subject application. More specifically, this device was fabricated in the following manner.

Using commercially available FLC mixture material (Merck: ZLI-4851-100), photo-curable the liquid crystalline material (Dai Nippon Ink Chemicals: UCL-001), and photo initiator material (Merck: Darocur 1173) based on JP-A H11-21554 (Japanese Paten Appln. H09-174463), PS-V-FLCD panel was fabricated. The mixture had 93 mass % of ZLI-4851-100 FLC mixture, 6 mass % of UCL-001, and 1 mass % of Darocur 1173.

The substrate used herein was a glass substrate (borosilicate glass, thickness 0.7 mm, size: 50 mm.times.50 mm; available from Nono Loa Inc.) having thereon an ITO film.

The polyimide alignment film was formed by applying a polyimide alignment material by use of a spin coater, then preliminarily baking the resultant film, and finally baking the resultant product in a clean oven. With respect to the details of the general industrial procedure to be used herein, as desired, a publication "Liquid Crystal Display Techniques" Sangyo Tosho (1996, Tokyo), Chapter 6 may be referred to.

For the liquid crystal molecular alignment material, RN-1199 (Nissan Chemicals Industries) was used as 1 to 1.5.degree. of pre-tilt angle alignment material. Thickness of the alignment layer as cured layer was set at 4,500A to 5000A. The surface of this cured alignment layer was buffed by Rayon cloth (mfd. by Yoshikwa Kako, trade name 19RY) in the direction of 30.degree. to center line of the substrate

shown in FIG. 17. The contact length of the buffing was set to 0.5 mm at both substrates.

<Buffing Conditions>
Contact length of the buffing: 0.5 mm
Number of buffing: once
Stage moving speed: 2 mm/sec.
Roller rotational frequency: 1000 rpm (R=40 mm)

Silicon dioxide balls with average diameter of 1.6 μm were used as space. Obtained panel gap as measured was 1.8 μm. The above mixed material was injected into the panel at the isotropic phase temperature of 110.degree. C. After the mixed material was injected, ambient temperature was controlled to reduce 2.degree. C. per minute till the mixed material showed ferroelectric phase (40.degree. C.). Then by natural cooling, after the panel reached room temperature, the panel was applied 10 V, 500 Hz of triangular waveform, 10 minutes (by use of a function generator, mfd. by NF Circuit-Block Co., trade name: WF1946F). After 10 minutes voltage application, 365 nm of UV light was exposed keeping application of the same voltage (by use of a UV light, mfd. by UVP Co., trade name: UVL-56). The exposure power was set to 5,000 mJ/cm2.

The initial molecular alignment direction of this panel was same with the buffing direction. The electro-optical measurement of this panel showed analog gray scale by application of triangular waveform voltage.

(2) Confirmation of peak-shaped current

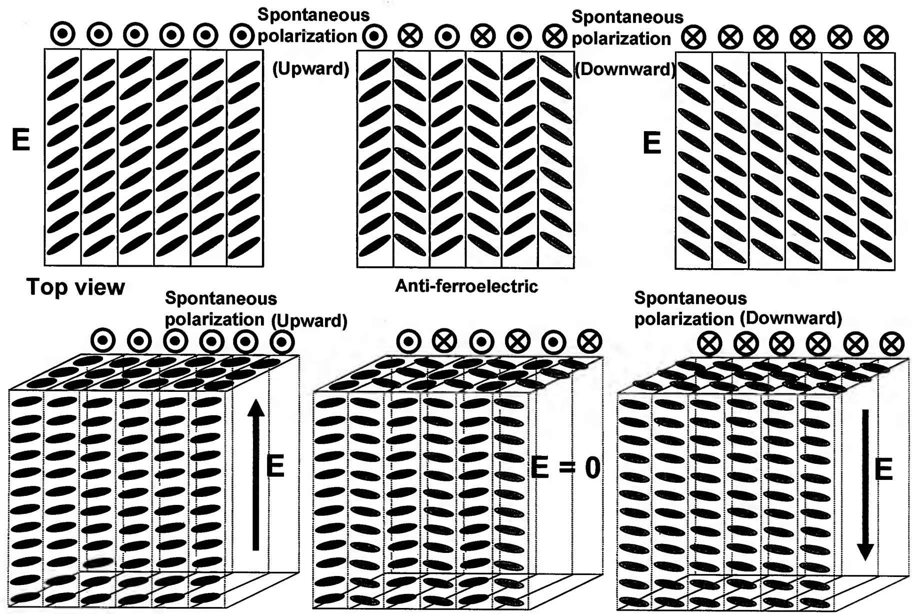
By use of the thus fabricated device, the presence or

absence of a peak-shaped current (i.e., polarization switching current during molecular orientation switching under an applied triangular waveform voltage) generated thereby was confirmed in the same manner as in Experiment 1.

I, the undersigned declarant, declare further that all statements made herein of my own knowledge were true and that all statements made on information and belief were believed to be true, and; further, that these statements were made with the knowledge that willful false statements and the like so made were punishable by fine or imprisonment, or both, under section 1001, of Title 18, of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

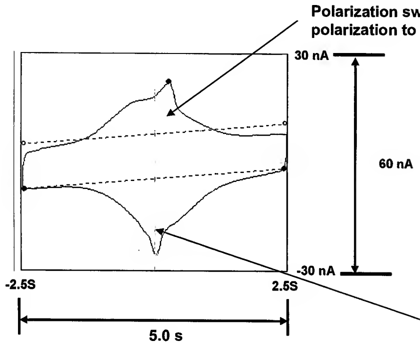
Signed this 26th day of March, 2008

Akihiro MOCHIZUKI



~~Figure 1.~~
Fig. 1

Spontaneous polarization at Anti-ferroelectric panel



Switched spontaneous polarization is:

$Q = 36\ nC/cm^2$

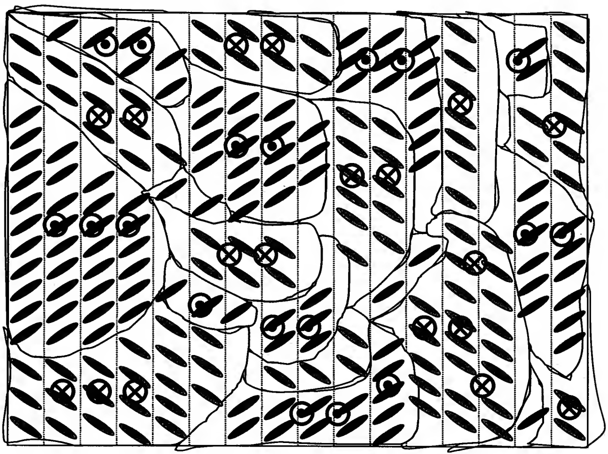
Switched spontaneous polarization is:

$Q = 27\ nC/cm^2$

Tanaka (USP 5847799)

Fig. 2

Kita~~mura~~ Iyama (USP 5583682), Takatori (USP 6040889)



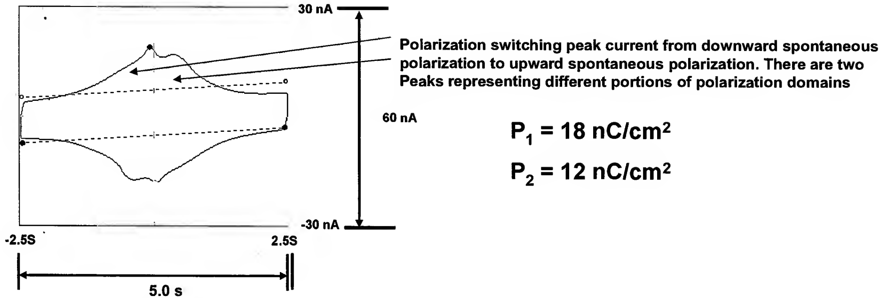
Spontaneous Polarization (Upward)

Spontaneous Polarization (Downward)

Top view

~~Figure 3~~ Fig. 3

Polarization switching peak currents representing Different domains of polarizations



$P_1 = 18\ nC/cm^2$

$P_2 = 12\ nC/cm^2$

Kita~~mura~~ yama (USP 5583682), Takatori (USP 6040889)

Fig. 4

Polarization switching peak current at mixed polarization panel

Cases of Kita~~mura~~ yana (USP 5583682), Takatori (USP 6040889)

$$I(t) = I_C + I_{P1} + I_{P2} + I_i$$

I_{P1}: Polarization switching peak current 1

I_{P2}: Polarization switching peak current 2

C: Total Capacitance of a panel

i: Constant Current through a panel

$$I(t) = I_C + I_{P1} + I_{P2} + I_i$$

$$= C\frac{dV}{dt} + \frac{dP_1}{dt} + \frac{dP_2}{dt} + \frac{V}{R}$$

Fig. 5

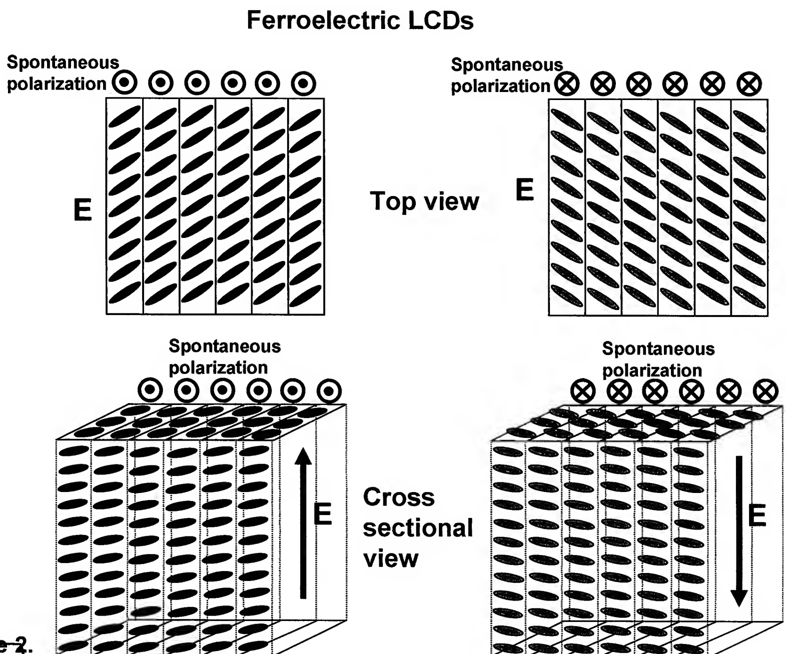
$$I(t) = I_C + I_{P1} + I_{P2} + I_i$$

$$= C\frac{dV}{dt} + \frac{dP_1}{dt} + \frac{dP_2}{dt} + \frac{V}{R}$$

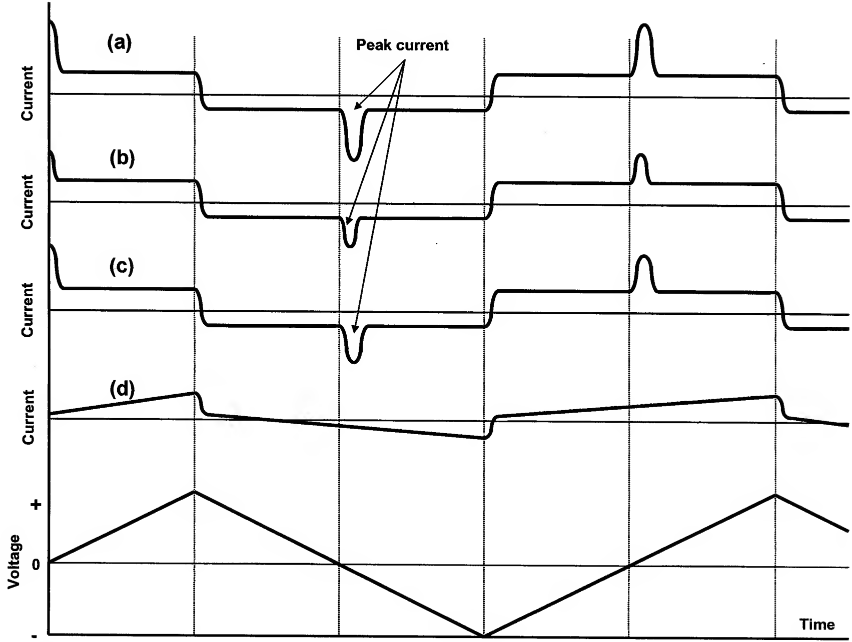
$P_1 = 18\ nC/cm^2$

$P_2 = 12\ nC/cm^2$

Fig. 6

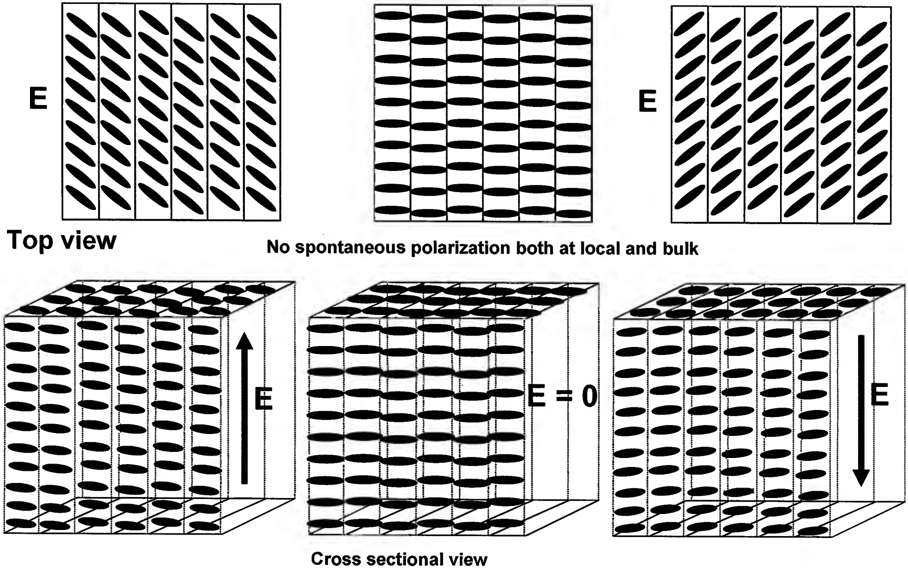


~~Figure 2~~. Fig. 7



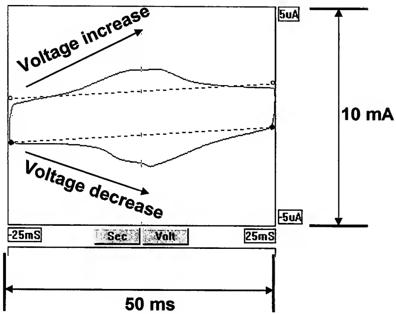
~~Figure 5.~~
Fig. 8

No polarization switching peak current at this Invention



~~Figure 4.~~ Fig 9

No spontaneous polarization switching peak current at the Invention



No spontaneous polarization switching peak current is observed at this Invention. Only monotonically increased current which is common to non-spontaneous polarization base one is observed. This is a direct evidence that the Invention does not have both local and bulk spontaneous polarization unlike references which have local spontaneous polarization clarified polarization switching peak current.

Fig.10